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THESIS

^{THAYER}
ALFRED THAYER MAHAN AND SPACE: A NECESSARY UNITY

by

Mark T. Sandvigen

June 1986

Thesis Advisor:

James G. Taylor

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Thayer
Alfred Thayer Mahan and Space:
A Necessary Unity

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis is an unclassified examination from a Western perspective, of the current and projected space efforts of the world and how they effect current U.S. Space Policy. There is currently no universally accepted space strategy to help in meeting the policy goals of the United States. It is the hypothesis of this thesis that the strategies needed to deal effectively with future space development were layed down in the past by Alfred Thayer Mahan and others. In order to outline a current strategy an analysis was conducted of current space programs, future space efforts, orbitology/orbital mechanics, and the writings of H. Jomini, A.T. Mahan, and Sir Julian Corbett. In order to manage and arrange the large knowledge base, a systems model was developed and used in this analysis. Upon the completion of the analyses, a blending of the Mahan and orbital mechanics was conducted in order to show, by analogy, that there exist parallels between that of naval strategy and strategies needed to reach US policy goals.

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I. INTRODUCTION

As the spacefaring nations of the world race pell-mell into the twenty-first century in their quest for quick solutions to complex problems, one has to ask what it is that guides all this activity? For some, space is a theater to be controlled, while for others it is a place of hope where the problems of over population and resource depletion can be studied and somehow managed, and for still others it is a combination of the two.

Through treaty and policy statements the United States of America falls into the latter category. The rationale for this is stated in the US National objectives which pertain to space [Ref. 1:p. 2]:

1. Strengthen the security of the United States.
2. Maintain US Space leadership.
3. Obtain Economic, Scientific benefits through exploitation of space.
4. Expand US private sector investment and involvement in civil space/space related activities.
5. Promote international cooperative activities which are in the national interest.
6. Cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

The Soviet Union, our chief competitor, has a space doctrine which is derived from the Marxist-Leninist dialectic which states [Ref. 2:p. vii]:

The Soviet Armed Forces shall be provided with all the resources necessary to attain and maintain military superiority in outer space sufficient both to deny the use of outer space to other states and assure maximum space based military support for the Soviet offensive and defensive combat operations on land, at sea, in air, and in outer space.

Rationalized thusly [Ref. 2:pp. viii],

. . . The current Soviet stance, refusing to admit the existence of any military element in their space program can only mean that the Soviet Leadership, rather than merely countering US moves, is actually seeking military superiority in outer space for offensive, as well as defensive purposes.

As can be seen the US Space Policy and the Soviet Space Doctrine are loosely in parallel when describing the need for national security. The first sign of divergence is in item two where the US has stated that it will be the technological leader in all fields of space endeavor, while the Soviet Union has but one goal, which is the support of its military. The final point leaves the US with a paradox. The paradox lies in the fact that the United States, by policy statement, has agreed to maintain the freedom of space to a nation that is working for systematic denial of this crucial arena to US and other international interests. It is to this problem that this thesis will address itself.

While the US has a space policy, it does not currently possess a space doctrine. In the absence of a formal doctrinal statement the US Air Force has created a combination Aero-Space doctrine which, by its own admission, falls short of meeting the goals of the US Space Policy declaration [Ref. 3:pp. 13-24]. If the only existing doctrine falls short, then where are the guiding strategies for the implementation of the US Space Program? It is the hypothesis of this thesis that the strategies needed to fulfill the policy goals, as set forth by the US Government have already been laid down in the fundamental * doctrines of H. Jomini, A.T. Mahan, Sir J. S. Corbett, and others. By looking at their guiding axioms it is hoped that through analogy ** an infinite variety *** of options will become available for use. It is this requisite variety which will

* Fundamental doctrine is grounded in an examination of history, and it applies in all operating mediums in any nation. Instantly recognized as elements of fundamental doctrine are purposes of the military, the nature of war, and the relationship of the military to other national instruments of power. Since fundamental doctrine is characterized by its timeless significance and universal application, it is rarely, if ever, rewritten in response to technological change [Ref. 4:pp. 40-48].

** Analogy is a first order approximation of unlike objects.

*** Variety in this sense, is as mentioned in J.G. Taylor's work on the , "Initial Concepts of Soviet Command and Control" [Ref. 5], when he quotes Terekov [1983, p.172] as saying, " Variety ... is created by the presence of reserves, surplus of both information and also physical characteristics ... Without reserves and redundancy

allow the US to meet its policy goals while at the same time insuring it will not be cutoff from outer space.

In attempting to prove the above hypothesis, a systems model (as first described by C. West Churchman) will be utilized to organize and handle the volume of information in existence. [Ref. 6:pp. 8-10]. The model was chosen for its ability to integrate disparate volumes of knowledge into a system *. One of the benefits of this method is the ability to test the entire undifferentiated ** knowledge base in order to make a determination as to how it affects the system design, thereby giving some degree of confidence as to the systems validity. Once the system is integrated, one will be able to observe the synergistic effect of all its parts working in concert. This synergistic effect is what creates the appropriate strategy, which is another rational for choosing integration *** over further differentiation.

effective control in the presence of random disturbances is unrealizable".

* A system is defined as a set of parts coordinated to accomplish a set of goals [Ref. 4:p. 29].

** The obsessive scrutiny, or further differentiation of information which is already vast in scope would hopelessly mire the hypothesis in a morass of superfluous detail.

*** Integration is the summing of all the parts in order to observe their workings as a whole, whereas differentiation is the reduction of the system into smaller and smaller pieces in order to determine their individual functions.

The process of differentiation will come later, as it should, when a strategic option is broken down to its constituent pieces and analyzed to find optimum solutions.

The information base which will be utilized within the model will include:

1. Current space efforts and trends.
2. Future space analysis.
3. Pre-existing doctrines.
4. Orbital mechanics (an energy perspective).
5. Doctrine management through orbital mechanics.

It is not the purpose of this thesis to present a rigorous analysis of each of these areas, but more to present them in such a manner as to give the reader a 'flavor', for what is currently ongoing in space and the problems faced in strategic management.

II. THE MODEL

The use of the systems model provides a structure by which an effective discussion of space strategy can be achieved. It accomplishes this by organizing large volumes of disparate information into a coherent framework. This framework is created by testing the knowledge base currently being analysed, which establishes the relationships of one body of knowledge to another. In addition, these relationships, within the models framework, allow the observer to conceptualize the ebb and flow of communications between various components of the system, Figure 1.

These communications allow the creation of a variety of responses needed to fulfill the goals of US Space Policy. In order to achieve these goals Churchman's model divides the body of the system into five parts which are as follows [Ref. 6]:

1. The objectives of the total system together with performance measures.
2. The systems environment.
3. The resources of the system.
4. The components of the system.
5. Management of the system.

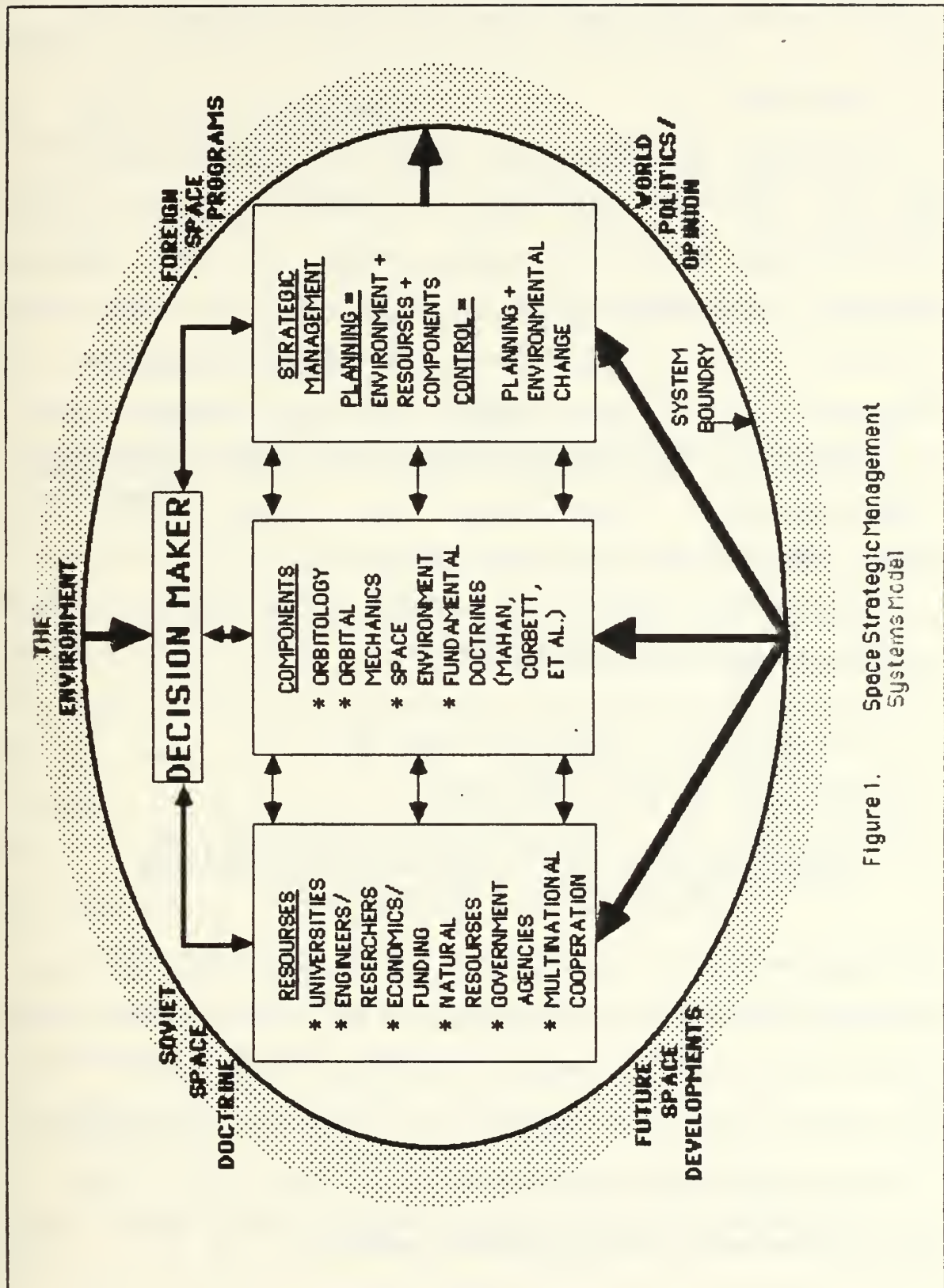


Figure 1. Space Strategic Management Systems Model

Each of the above considerations will be taken in turn and applied to the previously mentioned areas of study.

A. OBJECTIVES

Objectives are the goals or ends to which a system tends [Ref. 5]. This goal seeking, or teleology * was first described by Aristotle in his works on, "Man and His Universe". Churchman takes this concept of teleos and proposes a principle of primacy. This principle is a way to distinguish a real from a stated objective by asking whether a system will knowingly sacrifice other goals to obtain the stated objective. If the answer is , 'yes' , then the stated and real objective are identical.

To apply this test, a restatement of the US Space Policy is needed, and is as follows [Ref. 1]:

1. Strengthen the security of the US.
2. Maintain US Space leadership.
3. Cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

To look at the policy we have to ask whether the US would knowingly sacrifice statements 2,3 or both to maintain its stated objective. The answer is believed to be 'yes'. At this point there is a statement of primacy and the arguments

* Aristotelian logic views objects as wholes and as such are endowed with intrinsic goals (teleos).

put forth previously can be explained using Churchman's model.

B. THE SYSTEMS ENVIRONMENT

The environment includes all that lies outside the systems control. This at first seems obvious, but the argument is deeper. The environment in part controls how the system performs. As stated by Schoderbeck in his work on, "Management Systems" [Ref. 6:p. 10],

Both features must be present simultaneously: the environment must be beyond the systems control and, secondly must exert some determination on the systems performance.

Taking this statement and applying it to: (1) Foreign Space Programs; (2) The Future of Space; (3) Orbital Mechanics/Orbitology; (4) and Pre-existing Doctrines; it can be shown that the environmental influences will consist of Foreign Space Programs and the Future of Space. For example: There is little the US can do to influence the Soviet Union's space program but, it has a direct impact on US space policy. It is therefore, environmental.

On the other hand, orbital mechanics can be manipulated along with fundamental doctrines to achieve systems goals. It therefore, must be something else.

C. RESOURCES

Resources by definition reside within the system [Refs. 5,6]. They are the means available to the system for the

execution of activities necessary for goal realization. While this thesis will not delve into this aspect of the model, it should be noted that this is truly the strongest/weakest part of the US space policy. Resources available to the system are funding, equipment, people, and opportunities.

D. COMPONENTS

The components of the system are the activities the system must perform in order to meet its goals [Refs. 5,6]. It is the contention of this thesis that orbital mechanics and fundamental doctrines fit into this category. It is believed that orbital mechanics must be balanced against strategies and doctrines of Jomini, Mahan, Corbet, et.al in order to achieve the goals of US space policy. This previous statement is a paraphrase of Churchman, who believed that components when blended together make a mission. It is therefore, the goal of the mission components to achieve the desired objectives [Ref. 5:pp. 41-43].

E. MANAGEMENT

In this phase of Churchman's model, management encompasses two basic functions: planning and control of the system. Planning as stated by Schoderbeck [Ref. 6:p. 11],

Planning involves all aspects of the systems previously encountered, viz., its goals or objectives, its environment, its utilization of resources, and its components or activities.

Control of the system is much more difficult as there is the execution of planning, plus the added dimension of change.

F. SUMMARY

From the previous discussion of the model it can be seen how the knowledge base has been broken into constituent parts by Churchman's model. It is through the use of this model, and its ability to integrate disparate information that the hypothesis will be tested. If indeed the fundamental doctrines of Jomini, Mahan, Corbett, and others apply to space then our ability to control the system and plan for change can be realized.

III. ENVIRONMENT

A. INTRODUCTION

The environment as stated has an effect on the system, while the system has no control on the environment. From this point forward, the system referred to in this paper will be the Space Policy of the United States. The exploration which will be conducted will try and illustrate the complexities faced by the United States upon implementation of its policy within the environment. The environment, composed of foreign space programs and the future of space, will provide the backdrop against which a strategic systems model hopes to be developed. As a precursor for this discussion it is assumed that the reader has a fundamental understanding of the US Space Program and its goals for the next 10 to 15 years.

B. FOREIGN SPACE PROGRAMS

The nations that were chosen for this study stand out from the rest of the world operators of satellite equipment in a number of important ways. First of all, these nations have all independently launched vehicles into space. One can draw from this fact, that all of the countries possess their own facilities, down range tracking sites, processing

equipment, and most importantly, the knowledge and technology base needed to accomplish these feats.

Upon identifying the efforts that have gone into their individual programs, an investigative look will be taken into why these countries have gone to the expense of fielding these programs. While looking at these ongoing efforts, this report will try and identify current areas of research and development and what goals can be reached by putting these projects into orbit. Finally, there will be an attempt to identify current trends in these programs, and how these trends will effect ongoing U.S. efforts in space.

Upon the completion of the current space efforts a look will be taken as to what scientists, engineers, and other technical diciplines beleave to be the long range future of outer space development. It is this long range forecast which when analysed can reduce the uncertainty involved in implementing a space policy. This will be a critical element in the reduction of environmentally introduced change which causes system planning to go awry.

1. China in Space

China, whose space program has come as a surprise to many, is not new to the arena of outerspace. In a study by David [Ref. 8:p. 25] it was stated that, " China's burgeoning space capability is evidenced by twelve successful satellite launchings since April of 1970. With its first satellite, the Peoples Republic of China became

the fifth nation--after the USSR, USA, France, and Japan--to launch an artificial satellite using its own launcher."

In a study on the Chinese space program, Rao [Ref. 14:pp. 14-17] puts forth the argument that while China would like to become competitive in the world launcher market there are many problems to be solved before this becomes a reality. The most perplexing of China's problems is that of an immense population and land mass. To rectify this deficiency the Peoples Republic of China is importing two advanced direct broadcasting satellites which are designed to extend radio and television to all of her one billion plus population. China also plans to build and launch an earth resources satellite that will aid in emergencies (aviation transponders), water conservation, agriculture, and land use planning.

Both Rao and David [Refs. 8,14] state that to date most of the Chinese spacecraft have been designed for either military surveillance or technological development. With continued development it is believed by David [Ref. 8:p. 25] that China could have, "... initial astronaut flights by the end of the decade."

2. India in Space

In a country where the bullock cart is still the primary mode of transportation the push into space seems a glaring paradox. In a study by Rao [Ref.8:16-19] it is stated that, "... India has been propelled to join the

ranks of the spacefaring countries by the immense promises held out by space technology to solve the problems of poverty and backwardness." This paraphrases nicely the statement by Professor Satish Dhawan, head of the Indian Space Research Organization (ISRO), that, "The main aim of the Indian space program is towards the development of communications and earth observation satellite systems suited to India's needs."

To this end Rao [Ref. 8] notes that India has made dramatic breakthroughs in booster technology. The successful flight of the SLV-3 made India the seventh nation to join the ranks of spacefaring countries. With the ability to launch, India has moved forward with an aggressive earth observation satellite program. With one platform already in orbit, Bhaskara-1, the next step will be an infra-red remote sensing satellite (IRS). It is hoped that the information from these platforms will provide the needed data to help manage India's agriculture, forestry, meteorology, and hydrology.

Rao [Ref. 8] makes further mention of India's innovative techniques in communications satellites. After a series of loaner satellites from the United States and Europe with which India conducted her Satellite Instructional Television Experiment (SITE), ISRO was able to create from the combined technologies INSAT-1. INSAT-1 became the world's first 3-axis stabilized, geo-stationary,

television broadcast, telecommunication, and meteorological satellite.

Despite some early setbacks with INSAT-1 India's space effort continues to be geared towards creating the solutions that will help solve her numerous problems on the ground.

3. Japan in Space

A nation that has made large strides in the past few years in developing its space program, is Japan. As stated by Davis [Ref. B:p. 9] " Japan was the fourth country to launch a satellite, and the third to successfully launch a geostationary satellite with their own vehicle." From the preceding observation, it is seen that Japan is developing a credible space effort which includes its own tracking, launch and recovery facilities.

Due to the topographic limitations of an island nation such as Japan, the space program has been oriented in such a way as to alleviate many of these problems. A further description of the program by Davis [Ref. B] shows that Japan launched two communication satellites, CS-2A and CS-2B, to establish an emergency network for the earthquake prone islands. In addition to the emergency systems will be launches containing operational broadcasting satellites, BS-2A and BS-2B, which will reach the homes of over 500,000 Japanese. In early 1987, there are plans to launch an innovative marine observation satellite, MOS-1, that will

produce information for use in optimizing Japan's fishing industry. It is hoped that the data from MOS-1 will create a 10% to 20% reduction in the current fuel costs for the fleet.

In a study done on Asia in space, Radhakrishna Rao [Ref. 14] describes Japan's booster technology efforts. These efforts are manifested in the National Space and Development Agency of Japan's (NASDA), development of the billion dollar H-2 vehicle, which is described as Japan's workhorse of the 1990's. Rao [Ref. 14:p. 14] further states that, " The 45 meter H-2 is capable of placing two ton class spacecraft into geo-stationary orbit, and will also allow Japan to compete with both the American space shuttle and the West European Ariane vehicles for commercial business from the third world." His study also shows that Japan is conducting its own deep space missions with probes to Halley's comet, and observation platforms which can observe X-ray stars by both optical and radiosopic means.

In an overview of Japan's broad and technologically advanced program Davis [Ref. 8] points out that Japan will continue to solve the problems unique to an island nation, while simultaneously advancing her space capabilities inorder to compete more favorably with established space programs.

4. Canada in Space

A nation whose space program has made steady progress but, whose efforts have been overshadowed by her southern neighbor, is Canada. Day's study [Ref. 8:pp. 19-21], indicates that Canada became the third nation to develop, and orbit a satellite. Alouette 1 (the Lark), was designed as an ionosphere data satellite and continued to send useful data for over ten years. With proven technology Day [Ref. 8] illustrates that the Canadians set about to solve their own unique set of problems. With a landmass second only to the Soviet Union, Canada's efforts were directed to solving problems of distance. The solution to these problems was for Canada to divide her space program into four distinct areas each with teams devoted to research and development. The four areas were space sciences, communication, remote sensing, and navigation.

These teams working in concert, created a burgeoning space program. In conquering the 'communications distance problem', Day [Ref. 8:p. 20] states that, " Virtually every government department benefits from the data transmitted from space. The country has perhaps the most up-to-date communications network on earth. Radio, television, and telephone services are available in the remotest northern settlements. Daily newspapers are transmitted to the East and West coasts." In addition to what appears to be a first class communications system, the

most spectacular and best known contribution from Canada's space program is the remote manipulator arm, Canadarm. It is this device states Day [Ref. 8:p. 20] that, "...makes the U.S. space shuttle a viable tool." He further enumerates Canada's space contributions by mentioning the ultra-violet auroral imager for Sweden's Viking satellite, and many life science experiments for Spacelab.

Canada, based on current trends, will continue to look for unique solutions for conquering the dimensions of her large landmass. In addition, there will continue to be further participation in the shuttle program along with current plans for magnetic field modules, 1 meter space telescopes (Starlab), and a Radarsat for the determination of the ice edge. In addition, according to Day [Ref. 8], Canada also plans on continuing to play a integral part in the United States construction of a manned space station.

5. Europe in Space

" In 1975 there was flurry of excitement and hope for future cooperation as the United States and the Soviet Union joined hands in space for the first time. That soon faded and it has become apparent that the United States chief partners and toughest competitors are the Western European Nations [Ref. 8:p. 21]. " A Space World Staff report [Ref. 8] has shown that this competition has become more evident as we enter the latter half of the 1980's. This report further states that this will be continuing trend.

This is due primarily to the fact that the European Space Agency (ESA) is involved in every field of space science as is the U.S. National Aeronautics and Space Administration (NASA).

Spacelab was built to allow the U.S. space shuttle the flexible means of carrying scientific cargos into space. The European Space Agency has taken the next logical step and is studying the possible applications of spacelab technology to the space station which is slated for construction in the early 1990's. The Europeans have also put a great deal of research and development into Eureka, the European Retrieval Carrier. Eureka is designed to be deployed by the shuttle for six months of independent operations and then later retrieved. [Ref. 8]

The Ariane booster program was started at the behest of the French who feared that the free world launcher market would be dominated by the American space shuttle. The success of this venture was enough that the U.S. cancelled plans for a fifth orbiter. To date, the Ariane program remains dynamic and progressive with follow on plans to produce Ariane 2 and Ariane 3. This will give an increased capability for launching bigger payloads into earth orbit, further encroaching into the current space shuttle market. A report by Mallette [Ref. 11], communicates that between 1986 and 1992, ESA hopes to field Ariane 4. Ariane 4 will be an extremely versatile launch vehicle capable of placing

2-4.3 ton payloads into transfer orbit. His report also adds, that this will be accomplished using a new concept of mixing various combinations of liquid and solid fuel propellant boosters. It is expected that the utilization of the combination concept on the Ariane 4 will decrease the cost of putting payloads into orbit by 60%.

In conjunction with the above two efforts the Space World Staff report [Ref. 8] shows that ESA has also fielded many scientific space probes, meteorological, remote sensing, and communications satellites. It also states that while there is a collective effort on the large projects previously mentioned many small endeavors are conducted by the individual member nations themselves. To this end Rhea [Ref. 12:pp. 8-23] has stated that, "West Germany will put \$900 million dollars into the U.S. space station over the next 10 years. ESA along with Japan will provide scientific modules and small free flying spacecraft." While these countries have the lead on the projects and they arrange contracts, construction, and launch facilities the programs still come under the auspices of the European Space Agency.

The next step for ESA as offered by Mallette [Ref. 11:pp. 242-250] will be the exploration and construction of multi-payload/multi-service satellites. These satellites are based on ESA's assumption that there is a need to develop systems which can 'grow' in orbit as the demand for the services increases. One such system concept is the

'cluster'. The 'cluster concept' consists of several co-operating satellites, located close enough together in geostationary orbit that the beam width looks like a point source from the ground station. This system has the ability to grow as the demand increases and can be made more effective by the ability to link all the satellites in the cluster either by direct docking connection or by a communications space-link. The power requirements for the 'cluster concept' are still in the conceptual stage but, it is believed that a satellite power module will be launched first which will provide for all the future power requirements of the system.

The Ariane booster program, space shuttle and space station participation, along with current satellite technologies will add immeasurably to ESA's technological data base. As stated by Firness [Ref. 13:p. 21] "...these programs will actually be stepping stones to the establishment of an autonomous European space complex in the year 2000, or thereabouts."

6. Soviet Union in Space

The world's largest space program, in launches per year, shows no signs of abatement. The Soviet Union has continued to expand its presence in all areas of space science and development in order to meet its strategic, economic and national goals of prestige. Two decades ago in a classified military publication, Military Thought, it was

stated that, " Mastering of space [is] the prerequisite for achieving victory in war [Ref. 10:pp. 22-26]. " It is to this end that the current family of vehicles were designed. These designs support more than one hundred launches a year, and combined with a new generation of systems will allow the Soviets, by the mid to late 1980's to increase their space program both in numbers and payload weight[Ref. 10]. To understand how this is to be achieved it is necessary to see how the program is broken down and what levels of effort are being expended to achieve long term goals in space. The percentages from the 1984 Pentagon estimate indicate the directions that their space programs have gone to date are :

(1) Military Payloads	70%
(2) Military/Civilian Payloads	20%
(3) Civil/Scientific Payloads	10%

The Soviet Union in fulfillment of the effort listed above maintains between 110 and 120 satellites in orbit, which is about the same as the effort put forward by the United States. Their functions include:

- (1) Reconnaissance and Surveillance
- (2) Command, Control, and Communications
- (3) ICBM Launch Detection and Attack Warning
- (4) Strategic and Tactical Targeting

- (5) Navigational Support
- (6) Meteorological Support
- (7) Anti-Satellite Operations

Along with this current effort in satellites, the USSR continues to pursue its manned space program. Their manning of the Salyut space station is nearly year around with its primary mission being that of support of the military [Ref. 14:pp. 118-145]. In addition to the military mission there are many experiments which seem to be a prelude for the next phase of Soviet space development. It is expected that the experiments will lead to a permanently manned Skylab sized space stations which are to be operational in the next two to three years, and a very large modular space station which will be operational by the early to mid 1990's. These two space station complexes are expected to house 6 to 8 personnel and as many as 100 personnel, respectively [Ref. 10:p. 24]. This will give the Soviet Union a very large manned space presence by the turn of the century.

The ten percent that the USSR allots to civil/scientific payloads has in many respects paid tremendous benefits. The information brought back by their planetary probes and landers have increased greatly our knowledge of the solar system. In keeping with this, the Soviet long range planning is making good use of much of this data in designing their manned mission to Mars in the

1990's. Much of this future mission will depend on the success of the new Soviet heavy lift vehicle, which is very similar to the old U.S. Saturn V. Once this heavy lift vehicle becomes a 'working' reality then the USSR will be able to launch into Low Earth Orbit (LEO) their own shuttle, reusable space plane, and construction materials for their space station effort. It is currently believed that most of the material will be boosted to a location near Salyut where final assembly will take place. It is also of interest that the large ship that will take the Soviets to Mars is to be completed in space using the experience gained from the construction of their space stations [Ref. 16:pp. 20-24].

As can be seen the Soviets have very far reaching and well planned objectives for reaching their goals in space. Within the next ten to fifteen years there will probably be many more surprises as this effort moves forward.

7. Islamic Republics and Kingdoms

While the next group of nations do not readily fit with the original definition of space faring nations they will be include for the sake of continuity. These countries have the distinction of investing millions of dollars in ambitious programs that are now coming out of their infancy.

The Islamic Republic of Pakistan has begun a 10 year program that will provide space technology, research, and development for the country. In addition, Rao [Ref. 9:pp.

10-121 illustrates that the program will be geared toward a multi-purpose civilian program plus a determined effort to build a military launch vehicle capability. This latter desire is based on the belief that India's SLV-3 vehicle could be used against Pakistan in the role of an Intermediate Range Ballistic Missile (IRBM).

Pakistan's civilian space role will be much like her neighbor to the east, India. Plans are in place for direct television broadcasting, plus point to point communications. In addition, Pakistan has allocated 10 million dollars for a Landsat processing station located in Islamabad. The ten million dollars will also include a complete upgrade of existing ground receiving and tracking stations. There is also a determined effort ongoing to establish, The Islamic Space Institute. There is an anticipated initial investment of 3 billion dollars with the contributing partners being Bangladesh (East Pakistan), Egypt, Turkey, Indonesia, and Saudi Arabia [Ref. 10]

While these nations do not possess at this time all of the hardware to make them truly spacefaring nations, the framework and intent is there to utilize space technology to benefit them in the future.

C. THE FUTURE: INTRODUCTION

Space is a dynamic and vital endeavor which is ever changing. In order to develop strategies to deal

effectively with the variations caused by change, a careful look must be taken into what is believed to be the future. With many variations being technology related, a careful analysis can be conducted if the advancements that create change are broken down into: (1) 'breakthrough'; (2) and man driven.

Breakthrough technologies are the random variables in the equation of change which cannot be foreseen. It has been the pattern throughout history that major breakthroughs have altered the way we view the world and how we conduct our affairs, i.e. gun powder, discovery of the new world, invention of calculus, etc. The unpredictability of these breakthroughs and their ramifications is the reason this thesis will not dwell upon them. Instead, man driven technologies will be pursued in hopes that it will shed some light on future developments. In addition, it will be these man driven technologies that will be a partial backdrop for future space planning in order to meet the US Policy goals.

1. The Future: Near Term 1986-2000

The following discussion will lean very heavily upon data generated by the National Aeronautics and Space Administration. Due to the fact that the space station and the shuttle transportation system (STS), have in part been multinational efforts, it is felt that the data will also reflect many of the ongoing international space programs and be valid.

The US Space program plans to have in Low Earth Orbit (LEO) an orbiting platform by the 1990's. The question remains what next? A partial answer was given by Jesco von Puttkamer, Program Manager, Long Range Studies, NASA, when he stated [Ref. 18:p. 348],

... the existence of the space station will not only enhance Earth-orbital and deeper space ventures, but also (as a unique space research and development facility, operations base and transportation node) enable entirely new initiatives for human advancement in space not possible before.

Table 1. Useful Attributes of Space

•	Weightlessness (facilitates: special manufacturing activities, construction of very large delicate structures, and reliability of operations)
•	Easy Gravity Control
•	Absence of Atmosphere (unlimited high vacuum)
•	Ability to Utilize Materials/Elements that cannot exist in Earth's atmosphere (such as alkali metals, sodium, phosphorus, calcium, etc)
•	Comprehensive Overview (of Earth's surface and atmosphere, for: communication, observation, power transmission and other applications)
•	Isolation (from Earth's biosphere, for hazardous processes: little or no environmental, ecological or 'localism' issues)
•	Readily Available Light, Heat, Power (10 times rate on Earth)
•	Infinite Natural Reservoir (for disposal of waste products and safe storage of radioactive products)
•	Super-cold Temperatures (infinite heat sink near absolute Zero)
•	Large, Three-dimensional Volumes (storage, structures)
•	Variety of Non-diffuse (Directed) Radiation (UV, X-rays, gamma, etc)
•	Magnetic Field
•	Availability of Extraterrestrial Raw Materials (on Moon and asteroids)
•	Avoidance of Many Earth Hazards (Storms, Earthquakes, floods, volcanoes, lightning, unpredictable temperatures and humidity, intruders, accidents, corrosion, pollution, etc)
•	Potentially Enjoyable, Healthful, Stimulating or Otherwise Desirable for Human Well-being.

These initiatives are based on the usefull attributes of space listed in Table 1 [Ref. 18:p. 348]: von Puttkamer.

further states that based on long range studies of space, capabilities will advance in at least three major areas as follows [Ref. 18]:

- (1) Easy access to and return from space.
- (2) Permanent presence in Low Earth Orbit.
- (3) Limited self sufficiency of man in space.

For an illustration of man's current progress in space see Figure 2 [Ref. 18:p. 349]:

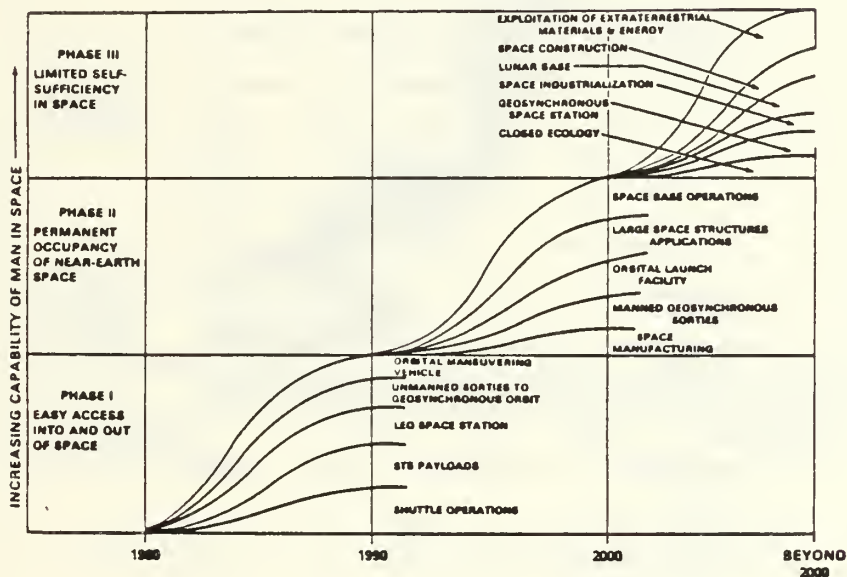


Figure 2. Man's Progress in Space

To achieve these goals the cost of getting into space must be lowered. The development of the Space Shuttle/Space Transportation System (STS) is a move toward the fulfillment

of phase one. The second phase will create the capability of sorting to geo-synchronous orbit (GEO) to aid in the construction and repair of large space objects and vehicles already in orbit. Phase three should lead to a closed cycle life support systems aboard space platforms in order to eliminate the need to transport these items from the surface.

In addition to the three phases mentioned above, it should be noted that these advancements are linked to certain key technologies. Based on current trends an attempt is made in Table 2 to project these technologies to the year

Table 2. Progress in Space Technology, Past and Projected

System	1960	1975	1990	2000
Payload capability (lb)	25	250,000	80,000 (reusable)	10 ⁶ (reusable)
Communications channels	15 (LEO)	15,000 (GEO)	10 ⁵ (GEO)	10 ⁷
Communication bit rate (Mars-Earth)	8	10 ⁵	10 ⁷	10 ⁹
Man days/mission	0.1	250	10 ⁵	5 x 10 ⁶
Resolution (km)	5 (LEO)	0.1 (LEO)	0.05 (GEO)	0.02 (GEO)
Data storage on-board (bits)	5 x 10 ⁶	2 x 10 ¹⁰	8 x 10 ¹²	16 x 10 ¹³
Energy storage (kW-hrs/lb)	0.02	40	800	1200
Active circuits (per cubic inch)	4	120,000	5 x 10 ⁶	10 ¹⁰ -10 ¹²
Space-borne computer speed (operations/sec)	2 x 10 ³	5 x 10 ⁵	3 x 10 ⁷	10 ⁸ -10 ⁹
Launch costs (1984\$/lb to LEO)	20,000	3000	1000	100-300
Position error (m)	1000	50	0.1	0.02
Failure rate (No./hr/Mbits)	10 ⁻²	10 ⁻⁴	10 ⁻⁶	10 ⁻⁷ -10 ⁻⁹

2000 [Refs. 8, 17]: An important feature in Table 2 is the man days/mission. Many of the construction elements of phase 2 and 3 will be man intensive. The initial

demonstration of mans ability to conduct these types of operations in space occurred during the Skylab missions [Ref. 19:p. 401], and the refurbishment of Salyut 6 by the Soviet Cosmonauts [Ref. 21:pp. 202-221]. The human role in space for the US Space Program is shown in Figure 3 which further elucidates man's progression in the space environment [Ref. 18:p. 349]:

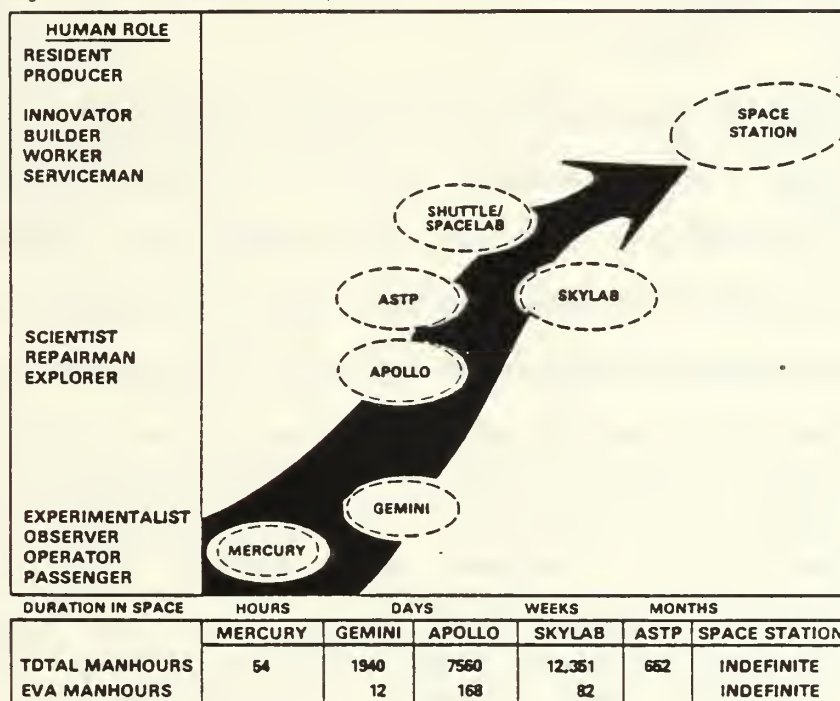


Figure 3. Man's Hours in Space

With the demonstrated ability to conduct complex operations in space, industrialization will soon follow. Based upon orbital selection, (see Appendix A), there will be corresponding industries which will be able to thrive in those environments. Due to the many properties listed in

Table 1, it is expected that Low Earth Orbit (LEO) will yield pharmaceutical products, high purity advanced semiconductors, unique glass materials, and glassy metals [Ref. 18]. The ability to move to geosynchronous altitudes holds the promise of large power generating facilities (due to the maximum avoidance of earth's albedo (reflection), and occultation), repair of existing satellites, debris removal, and larger and more powerful direct broadcast satellites [Ref. 22].

With the help of the infrastructure of government many of the above ventures will be private concerns [Ref. 22]. It is estimated that the world will be investing 75 billion dollars by 2050 based upon a growth rate of 2 percent [Ref. 18:p. 351]. If the return of seven dollars to the economy for every one invested can be expected based upon the figures of the Apollo missions [Ref. 25:p. 25] then, a two percent investment seems modest. The promise of continued profits becomes even greater if one leaves the earth's influence and ventures to the moon. A probable scenario for man's push into space is illustrated below in Figure 4 [Ref. 24:p. 11]:

2. The Far Future: 2000 and Beyond

The establishment of a lunar base has many philosophical and practical qualities. While the esoteric effects of settlement will not be discussed, there is no doubt it will be a landmark in human history.

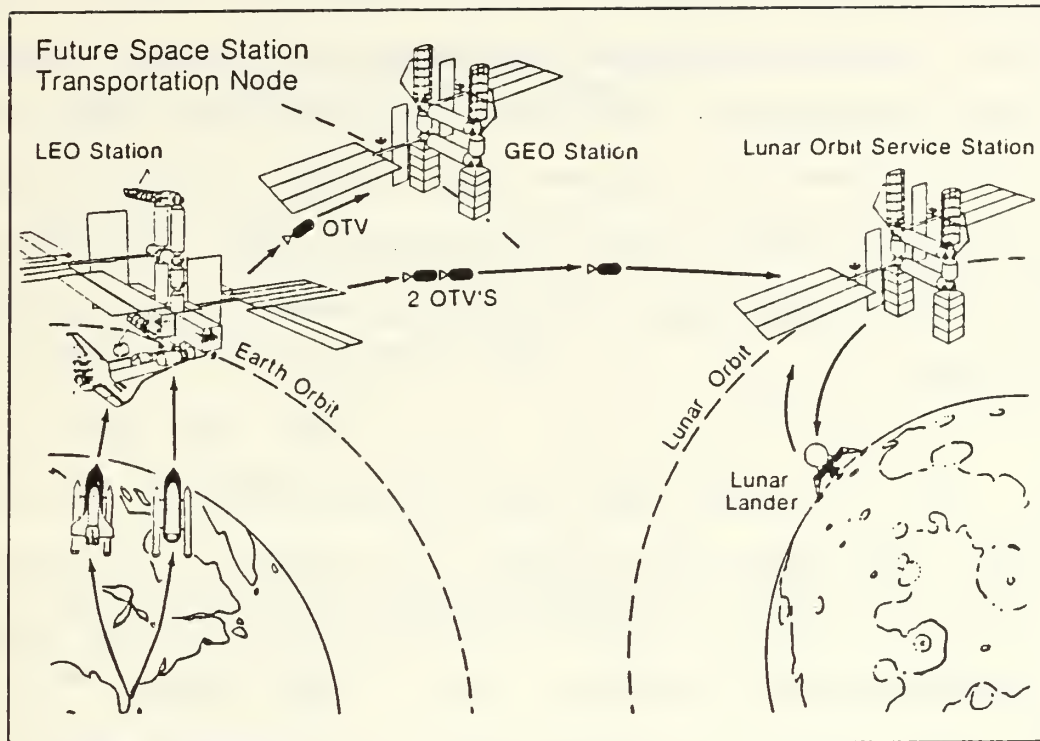


Figure 4. Man's Expansion in Space

The moon presents many other features which at this point are more motivating. If the development of lunar mining techniques, after settlement, are successful then metal extraction and the manufacturing of construction materials will be the natural follow-on to assaying, surveying, mining, excavation, gaseous oxygen production, and oxygen liquifaction [Ref. 24:pp. 370-371].

The lunar surface also offers an environment which might have important scientific, engineering, technological and research uses because of its low gravity, isolation, vacume, sterility, low background noise, Earth visibility,

low temperature variation, low magnetic field, long day/night cycle, unique geological features, and stability for large instruments, facilities, and structures [Ref. 24]. It is for these last reasons that the moon is being looked at as a future launch point for unmanned space exploration, space colony resupply *, and further manned interplanetary exploration.

Mankind's reach after making the transition from earth orbit to lunar bases and probable colonies at L4 and L5 seems to be just the beginning. Dr. Anthony R. Martin of the British Interplanetary Society, conducted a survey dealing with space in the far term. The results of the study were published in 1983 and serve to give an idea of what may be in store. The answers given were based on the assumption that man would have landed at least on the moons of Mar's (Phobos and Deimos) by 2005. The results of the survey are as follows [Ref. 27:p. 310]:

1. First manned mission to the Jupiter system.

Median date: 2029

IQR: 2024-2037 (IQR: the interval containing the middle 50% of the responses)

* Space colonies will most likely be placed at L4 and L5 because of their inherently stable positions. See orbitology section.

2. First manned mission to the edge of the Solar system. (Neptune/Pluto distance)

Median date: 2058

IQR: 2045-2070

3. Large groups (greater than 1,000) living in space (including the moon).

Median date: 2024

IQR: 2020-2030

4. Extensive use of the Solar systems natural resources, excluding the moon.

Median date: 2040

IQR: 2030-2050

5. Rapid, reliable transport within the Solar system.

Median date: 2040

IQR: 2030-2050

6. Detection of an extrasolar planet.

Median date: 1992

IQR: 1990-1995

7. First unmanned interstellar probe launched from the Solar System.

Median date: 2054

IQR: 2045-2060

8. First manned interstellar probe launched from the Solar System.

Median date: 2140

IQR: 2130-2200

9. Colonization of an extrasolar planet by a mission launched from the solar system.

Median date: 2260

IQR: 2110-2320

10. Development of Artificial Intelligence to a level equal to that of a human.

Median date: 2058

IQR: 2020-2071

3 responses of "Never"

11. Contact with extraterrestrial intelligence
(not necessarily communication)

Median date: 2066

IQR: 2050-2100

2 responses of "Never"

Whether these estimates will stand the test of time is open to conjecture. The reason for their inclusion is to show that there are space planners and engineers who are looking that far ahead. It is this insight and will to

dream which will creat tomorrows environment for US Space Policy.

D. SUMMARY

From the preceding discussion it is apparent that the United States and the Soviet Union are not alone in their conquest of space. The projected benifits of being in orbit have proved to be numerous, hence the tremendous effort put forward by the nations previously mentioned.

In order to solve the obsticles of topography China, India, Canada, and Japan have embarked on ambitious programs that will allow their dispersed populations the benefits of communication, television, and early warning broadcasts via satellite. These same four nations have also fielded earth observation and weather satellites in order to manage more effectively their resources.

The Soviet Union and ESA have much larger programs which field numerous satellites, both military and civilian, along with deep space efforts. As mentioned previously the Soviet Union's Space effort has been mainly military, and has been the backdrop for their manned space effort since the early sixties. ESA on the other hand has maintained a broad program base with many joint projects with NASA. It is predicted, that the knowledge gained from these ventures will give ESA the technological background for their own manned space effort by the year 2000.

The future in space for both man and machine will continue to expand. The technology will continue in basically two directions: (1) Augmentation of current earth assets; (2) and further the ability for man to live and work in space. While space in the far term is open to conjecture, it is apparent that there are goals in place for man's further exploration and settlement. It becomes apparent that the magnitude of these explorations, and consequent exploitations are huge. The ability of one individual nation to undertake the expense of one of these operations will be prohibitory. It is felt by many that the space ventures of the future will be a blend of multi-national concerns and the governments under which they operate. It will be through this cooperative effort that man makes his greatest strides.

This current and future environment that the US Space Policy must operate, is highly competitive; with the competition being not just military but economic as well. The continuing trends of these foreign space programs will only tend to exacerbate this situation. Therefore, the implementation of policy must be through future technological developments coupled with planning for coming eventualities.

IV. COMPONENTS

A. INTRODUCTION

Components of the model are the missions, jobs, or activities the system must perform to realize its objectives. As Churchman suggests, the components of this model are designed, not according to similarity of function, but according to similarity of mission. Once the components are analysed, then a blending of orbital mechanics and the axioms of Mahan will ensue to illustrate this similarity.

One of the vital components of the system model is that of orbital mechanics/orbitology. In order to understand the relation of Mahan to space activities, it is necessary that one have a rudimentary understanding of orbital mechanics and orbital topography.

B. ORBITAL MECHANICS: INTRODUCTION

A discussion of orbital mechanics will include a basic look at the energy relationships between velocity, motion in gravitational fields, and orbital geometry. The discussion will be extended to launch trajectories, co-planar orbital transfers, and intercepts (rendezvous). The purpose of this

analysis is to illustrate that spaceflight, in order to be economical, follows a least energy trajectory*.

In order to analyse these least energy relationships, a look at the underlying principles is in order. From the results of this analysis the various orbits will be briefly explained along with the corresponding transfer maneuvers. Finally a look at special cases will be conducted to show that the inter-relationships in the orbital geometries remain constant.

1. The Foundations

It was on Christmas Day, 1642 that Tycho Brahe and Johanne Keppler laid the foundations of orbital mechanics as we know it [Ref. 28:pp. 1-2].

Tycho, the noble aristocratic Dane, was exceptional in the mechanical ingenuity and meticulous in the collection and recording of accurate data on the positions of the planets. He was utterly devoid of the gift of theoretical speculation and mathematical power.

Kepler, the poor sickly mathematician, unfitted by nature for accurate observations, was gifted with the patience and innate mathematical perception needed to unlock the secrets hidden in Tycho's data.

Johanne Kepler's observations of Brahe's data are listed below [Ref. 28:p. 2]:

First Law: The orbit of each planet is an ellipse with the Sun at its focus.

* High energy trajectories will not be discussed due to their high CEP's (Circular Error Probable). These high CEP's are due to the small flight path angles flown by the vehicle.

Second Law: The line going from the planet to the Sun sweeps out equal areas in equal time.

Third Law: The square of the period of the planet is proportional to the cube of its mean distance from the Sun.

While these Laws are not qualitatively definitive they explain a great deal. It was not until Sir Edmond Halley, brought Sir Issac Newton's discoveries to light that the mystery of Keppler's Laws were explained.

2. Newtonian Mechanics

In 1687 Newton published, "The Principia Mathematica Philosophiae Naturalis". His discoveries are as follows [Ref. 29:pp. 47-50]:

First Law: Every body continues in a state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed upon it.

Second Law: The rate of change of momentum is proportional to the force impressed and is in the same direction as that force.

Third Law: To every action there is always opposed an equal reaction.

From the above three observations, now Laws of Physics, is derived Newton's Law of Universal Gravitation which is what governs space flight as we know it [Ref. 30:pp. 2-9]:

Every particle in the Universe attracts every other particle with a force that is proportional to the product of the masses and inversely proportional to the square of the distance between the particles.

While it is not the intention of this thesis to derive all the relationships, a dimensional analysis will be conducted to explain their correspondence to one another and the

subsequent effect they have on the space flight energy budget.

a. The Universal Law of Gravitation

In the formulation of the Universal Law of Gravitation Newton introduced the constant of proportionality, 'G'. The Universal Gravitation Law is stated mathematically as follows:

$$F = GMm/r^2$$

In orbital mechanics it is the usual practice to combine 'G' with the large mass and create a new constant 'μ'. This is done because the mass of the earth is usually very much greater than the mass of the second body (usually a satellite) which yields the new expression, $F = \mu m/r^2$. In addition if we chose the Earth as our reference point then the acceleration on the surface is due to gravity alone which yields $F = mg$. By equating Forces, $F = mg = \mu m/r^2$ and dividing through by a unit mass we find that gravity is inversely proportional to the square of the distance from our reference, $g = \mu /r^2$.

b. Energy

The laws of conservation of specific mechanical energy and specific angular momentum govern any body in space following a free flight path, whether it is a missile, a satellite, or a natural body. [Ref. 30:pp. 2-15]

To explain this statement further there needs to be the application of both Newton's Second Law and that of the

First Law of Thermodynamics [Ref. 29:p. 277]:

First Law: $\Delta U = \Delta Q - \Delta W$

Where: ΔU = The increase in the internal energy of the system.

ΔQ = The heat which flows into the system.

ΔW = The work done by the system.

Stated simply, the above equation says that energy can neither be created or destroyed but only converted from one form to another.

From the above equation we can show that the energy put into the system must equal the energy out of the system, or that KE (kinetic energy) = $-PE$ (potential energy). This conservation of energy is what determines whether or not a body will remain in orbit or leave the influence of the Earth forever. The following is a dimensional look at these properties:

The formula for Potential Energy is:

$$PE = - \mu m / r$$

To find the PE per unit mass we divide both sides by 'm'.

$$PE/m = - \mu / r$$

The formula for Kinetic Energy is:

$$KE = mv^2 / 2$$

Again, dividing both sides by a unit mass,

$$KE/m = v^2 / 2$$

From the previously defined relationships:

$$KE = -PE$$

$$0 = KE - PE$$

By substitution: $0 = KE/m - PE/m$

or: $0 = v^2/2 - \mu/r$

Therefore, the specific mechanical energy, 'E', of the system is defined as:

$$E = v^2/2 - \mu/r$$

This very important relationship has rather large ramifications for orbital mechanics of which the following are examples:

As 'r' (the radius), grows without bound, μ/r approaches zero leaving the energy of the system positive. A positive energy means that the body has enough energy to leave the system.

If the velocity begins to approach zero the body is captured by the system. Since the body is gaining potential energy it either never left the pad, or it is crashing into the larger body.

If the velocity needed for a particular orbit is constant then the equation translates into a linear relationship between payload and energy. This makes sense, for as one increases payload there is a corresponding increase in the energy needed to place it in orbit. If the energy output of the booster is fixed then a larger payload will have to go into a lower orbit. Payload is Energy!

c. In Orbit

The preceding discussion has shown in a much simplified way, the energy relationships which govern putting a vehicle in space. Once in space, the question

remains as how objects stay in orbit given a constant pull of gravity from the larger body. The answer lies in the energy equation, Newton's second law, and the inverse square law of gravity. Once in orbit the spacecraft has a momentum which is imparted by the mechanical energy at a particular orbital altitude. Newton stated that an objects uniform motion should be in a straight line unless acted upon by an outside force. The outside force is gravity, and it acts on this momentum and bends it into an orbit around the Earth. This change in momentum is exactly equal to the gravitational pull at that altitude.

Another way to visualize this concept was first put forward by Dr. Robert S. Richardson, an astronomer at Mt. Wilson Observatory [Ref. 34:p. 34]. His concept was that of a gravity well* around large bodies in space, see Figure 5 [Ref. 31:p. 57]:

This concept fit in well with what Newton had set forth. If one could visualize the fabric of space as a bed sheet, with globes of proportionate mass to the planets

* The Earth is at the bottom of a tapering gravity well 4000 miles deep.

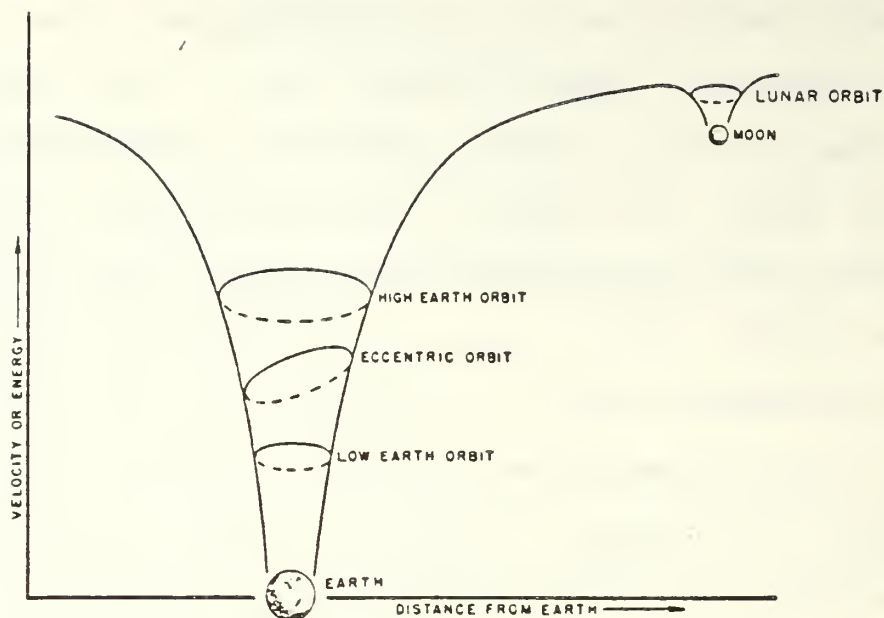


Figure 5. Gravity Wells Earth-Moon System

placed on that sheet, then the puckers created by the heavy globes would represent the distortion of space due to gravity. The walls of the gravity well diminish as $1/r^2$ and create the boundaries of the orbits at particular altitudes. As can be seen it takes more energy near the earth to climb out of the well, than it does at higher Earth orbits. If this were not true, then the Earth's gravitational pull would be infinite, i.e. a black hole.

d. Orbital Maneuvers

With the above energy relationships defined the following discussion will look at orbital solutions which

can be derived from them. Once there is a selection made for LEO, GEO, lunar, etc. the problem is getting there, see Figure 6 [Ref. 31:pp. 65-66].

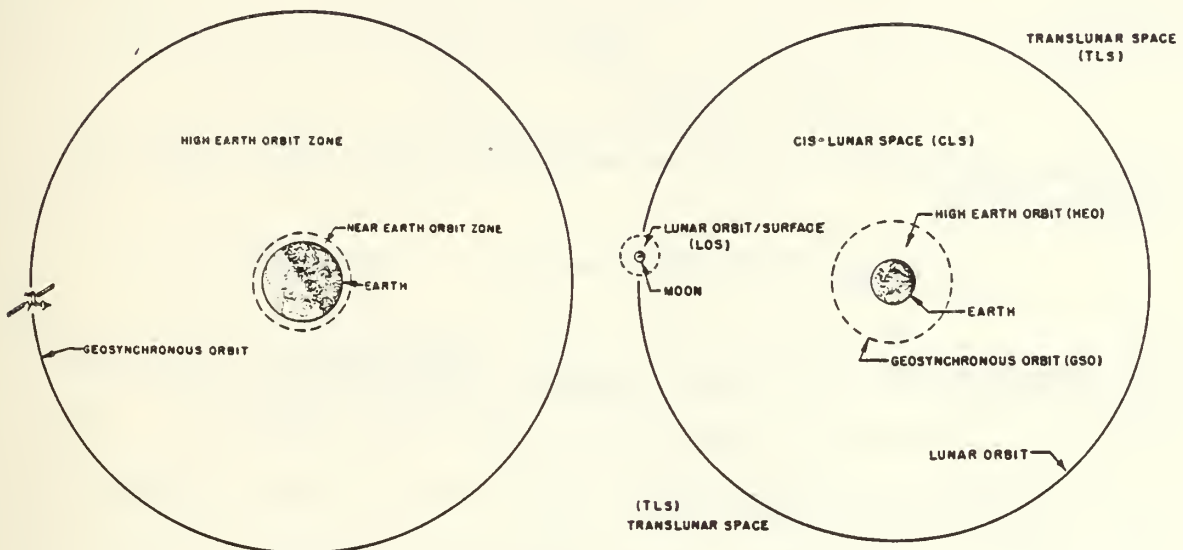


Figure 6. Space Topography (to scale)

Before a discussion is pursued on the launch phase into orbit, it would be wise to discuss the Hohmann transfer maneuver. The transfer between two circular co-planar orbits is one of the most useful maneuvers in orbital mechanics. It represents an alternative to high altitude direct injection orbits. What Hohmann recognized in 1925 [Ref. 32:p. 218] is that the least (ΔV) velocity change

required for the transfer between two circular orbits is achieved by using a doubly-tangent transfer ellipse. As illustrated in Figure 7 [Ref. 32:p. 219] the radius vectors r_1 and r_2 make up the semi-major axis of the ellipse with v_1 and v_2 being the tangential velocity vectors at the intersection between the two ellipses. Therefore, from geometry:

$$2a = r_1 + r_2$$

From an analysis of angular momentum [Ref. 33:p. 47] the relationship:

$$E = -\mu/2a$$

or

$$E = -\mu/(r_1 + r_2)$$

Now solving for V in the transfer from r_1 to r_2 :

$$E = v^2/2 - \mu/r_1$$

$$-\mu/(r_1 + r_2) = v^2/2 - \mu/r_1$$

$$-v^2 = -2\mu/r_1 + 2\mu/(r_1 + r_2)$$

$$v = \sqrt{2[\mu/r_1 + E]}$$

What the last equation represents is the minimum energy that must be added to the velocity at r to accomplish the orbital change. By using the above relationship one can also find the circular velocity of an orbit. In the circular orbit $r_1 = r_2$ so therefore, the final result is:

$$v = \sqrt{\mu/r}$$

This expression for orbital velocity also has some

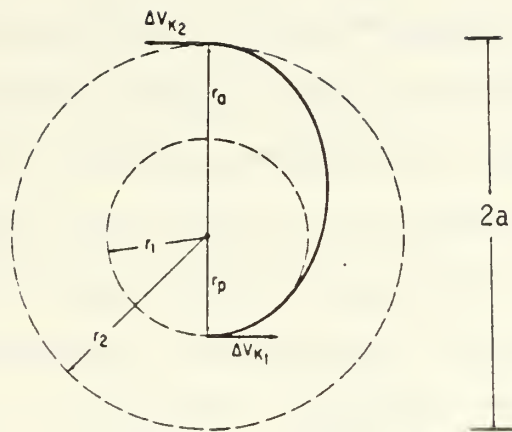


Figure 7. Hohmann Transfer Manuevers

interesting consequences. One can see that the farther away from the Earth one gets, the slower the orbital velocity. This makes intuitive good sense as a satellite in LEO orbits the Earth every 90 minutes, and a satellite at GEO orbits every 24 hours, and the moon (a special Earth satellite) orbits every 28 days.

e. Launch

When the mission coordinators plan to put a vehicle into orbit they use a modified Hohmann transfer ellipse. The modification is employed because of gravitational force loading on the airframe. The space launch is conducted so that the payload is continually propelled, except for brief interruptions during staging,

from lift off to final injection into an orbit or escape trajectory.

The initial portion of the trajectory begins with a brief period of orbital flight followed by a gradual pitch over sequence (programmed tilt) that deflects the vehicle into an angle of 40 to 50 degrees from the vertical. After the initial pitch over sequence the vehicle follows a zero angle of attack gravity turn which gradually deflects the velocity vector toward the horizontal, Figure 8 [Ref. 32: p. 2091:

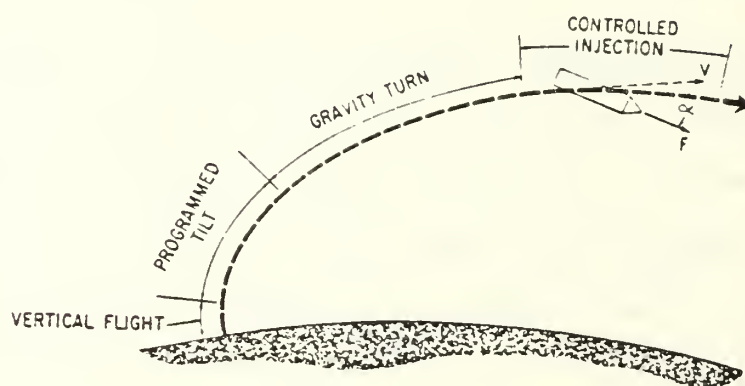


Figure 8. The Gravity Turn

This procedure is used for two major reasons; first, the thrust always acts in the direction of the velocity vector, and the gravitational force which opposes the thrust diminishes as the cosine of the angle between them. As the thrust vector approaches horizontal ($\theta = 90$

degrees) the gravity component approaches zero. The elegance in this maneuver is the utilization of the aerodynamic properties of the launch vehicle, plus the added benefit of using the rotational velocity contributed by the Earth. In the last phase of the ascent trajectory, corrections are made to ensure injection occurs at the desired orbital altitude. As an example, imagine the space shuttle sitting on the pad (r_1) having an initial velocity equal to that of the Earth's rotation (v_1). At lift off, energy is added in the way described above so that at the top of its trajectory (transfer ellipse) the velocity is what is needed at that altitude. Again the equation holds true:

$$v = \sqrt{2 \left[\mu/r_1 + E \right]}$$

f. Rendezvous

In order to rendezvous, the planner must take into account the relative motion of the object already in orbit. Once the intended movement of the orbiting vehicle is determined, it is a process of manipulating the orbital mechanics in such a way as to put the pursuing spacecraft on a 'collision' course. The new course is that of a Hohmann transfer such that the minimum energy employed puts the pursuing spacecraft at the point of intercept at the exact moment it is at the top of the transfer ellipse.

g. Orbits

The following discussion will lay out the topography of space as it is currently used for Earth observation, communications, and scientific exploration, refer to Figure 5 [Ref. 31]. The orbits are as follows [Ref. 31:p. 64]:

- (1) Earth's Atmosphere: This zone extends from the surface of the Earth to approximately 100 km. This zone contains most of the gaseous atmosphere, and presents a large impediment for launching space vehicles.
- (2) Low Earth Orbit (LEO): This zone extends from 100 km to 500 km. It is this area where most of the observation, navigation, detection, and ultimately where the space station will be orbited. This zone lies below the Van Allen Belts *.
- (3) High Earth Orbit (HEO): This zone extends from 500 km to 40,000 km and lies within the Van Allen Belts. Currently Geosynchronous Orbit (GEO), 36,000 km, is used for direct broadcast, some earth resources and tracking capability.
- (4) Cis-Lunar Space (CLS): This zone extends from 40,000 km to within 100 km of the lunar surface.
- (5) Lunar Orbit/Surface (LOS): This zone extends from the lunar surface to 100 km. This orbital parameter is the dividing line between CLS and Trans-lunar space.

* The Van Allen belts contain high energy particles which lie in concentrated layers around the Earth. These radioactive belts are concentrated between 500 km and 40,000 km.

(6) Trans-Lunar Space (TLS): This is approximately 390,000 kms from the Earth and extends to approximately 1,000,000 kms. This arbitrary line was chosen because the slope of the Earth's gravity well is approximately zero, with the solar gravity well being dominant.

h. Special Case

A special case within the earth-moon system is the Lagrange or Earth-moon libration points, see Figure 8 [Ref. 31:p. 60]:

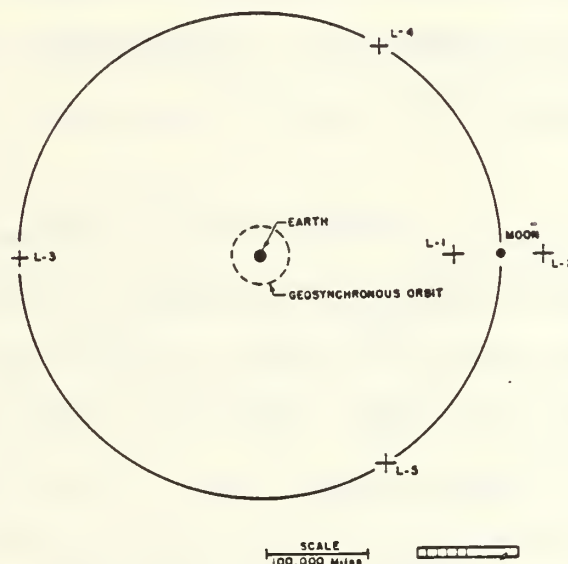


Figure 9. Earth-Moon Libration Points

As can be seen there are 5 libration points about the moon. They lie 60 degrees ahead and behind (L4 and L5), and 180 degrees ahead of the moon in its orbit (L3). The other two are in the Earth-moon line and lie 76000 km from the moon

towards the Earth, and 71000 km away from the moon from the Earth [Ref. 31:p. 59].

The libration points L1, L2, L3, are unstable, meaning that it would take an input of energy to keep an object place there stationary. The other two L4, and L5 are stable. This is a theoretical result of Lagrange's calculation of the three body problem [Ref. 31]. By analogy we know them to be stable because of two planetoids in the Jupiter-Sun system which occupy the same relational spaces which are stable. If one were to utilize the gravity well analogy, all the gravitational accelerations cancel one another out. leaving L4 and L5 stable.

3. Summary

It is the physics of the space environment which has dictated our approach to placing objects in orbit. Due to the extreme distances and the boundary conditions (gravity, energy, and resources), the approach used is the Hohmann transfer, or path of least energy. It is by the careful balancing of the energy budget against the orbital parameters that insures that we get the most payload in orbit for the resources expended. By paying attention to the parameters below:

1. Gravity follows an inverse square law.
2. Energy is constant, it can only be changed from one form to another.

3. There is an inverse relationship between energy input and system effect.
4. Payload is directly related to energy.
5. Spaceflight today is conducted using the Hohmann transfer maneuver, or path of least energy.
6. Orbits are chosen according to mission area.
7. There are stable and unstable areas in the earth moon system.
8. The distances are great and the time to cover them ranges from minutes to days.

we can perform a variety of orbital maneuvers, so consequently have a number of orbital options open for exploitation. These options can produce the methodologies by which we can achieve the goals of US Space Policy.

C. MAHAN AND THE LIMITS OF SPACE

Another equally powerful component of the systems model are the axioms of Mahan. The question is surely to arise as to why these axioms, and not something more contemporary? The answer is two fold, it is the belief of this thesis that A.T. Mahan gave, by analogy, a clear recipe for the coping for the initial stages of space exploration, exploitation, sovereignty, and control; and secondly, there is a tremendous similarity between the conflict in space and that of the seas, see Appendix 2 [Ref. 34].

The following discussion will lay a foundation for strategy by utilizing the axioms of Alfred Thayer Mahan, his predecessors and successors. When this has been

accomplished, these maxims will be blended with orbital mechanics to provide insight into achieving the goals of US Space Policy.

1. Mahan, a Man and His Times

Alfred Thayer Mahan, was invited to lecture at the US Naval War College after the completion of his first book, "The Gulf and Inland Waters", in the Civil War. In the course of preparing his lectures for the Naval War College, Mahan somehow found himself, rose above a career which until now he himself acknowledged had been nearly wasted, and exceeded all expectations by developing his famous trilogy to inaugurate a philisophical study of naval history: The Influence of Sea Power upon History, 1600-1783 (1890); The Influence of Sea Power upon the French Revolution and Empire, 1793-1812 (1892); and Sea Power and Its Relation to the War of 1812 (1905) [Ref. 35:p. 173]. A. T. Mahan wrote at a time when there was a great expansion of the world powers into colonial empires and strategic holdings. He wrote to insure that the United States would not be cut off from the sea and her livelihood by this very same colonial expansion [Ref. 35:pp. 174-177]. In order to achieve a perspective, Mahan looked to history for answers. It became apparent to him that the past had a great deal to say to the future. Mahan speaking to the value of historical study illustrated that [Ref. 36:p. 3],

The history of sea power is largely, though by no means solely, a narrative of conflicts between nations, of mutual rivalries, of violence frequently culminating in war. The profound influence of sea commerce upon the wealth and strength of countries was clearly seen long before the true principles which governed its growth and prosperity were detected. To secure to one's own people a disproportionate share of such benefits, every effort was made to exclude others, either by peaceful legislative methods of monopoly or prohibitory regulations, or, when these failed direct violence. The clash of interests, the angry feelings roused by conflicting attempts thus to appropriate a larger share, if not the whole, of the advantages of commerce, and of distant unsettled regions led to wars. On the other hand, wars arising from other causes have been greatly modified in their conduct and issue by control of the sea.

In his writings and teachings, Mahan was particularly influenced by the works of Henri Jomini, a Swiss theorist. It was Jomini who first put forth the strategy of the battlefield [Ref. 37:pp. 66-67]:

1. Selection of the theater of war, and the discussion of the different combinations it allows.
2. Determinations of the decisive points in the combinations and the most favorable direction for operations.
3. Selection and establishment of a fixed base and the zone of operations.
4. Selection of the objective point, whether offensive or defensive.
5. The strategic fronts, lines of defense, and fronts of operations.
6. Choice of lines of operations leading to the objective point or strategic front.
7. For a given operation, the best strategic line and the different maneuvers necessary to embrace all possible cases.

8. The eventual bases of operations, and the strategic reserves.
9. The marches of armies, considered as maneuvers.
10. The relations between the positions of depots and the marches of the army.

It was the genius of Mahan that recognised the similarities between Jomini's, 'Art of War', and that of naval strategy. With this as his backdrop, Mahan formulated his analysis. He condensed Jomini's writings and divided his strategic naval analysis into four interrelated areas: (1) The necessity for central positions or lines; (2) The necessity of interior lines of movement relative to central positions; and (3) the bearing of communications upon the force's ability to maintain itself and operate; and (4) concentration of force [Ref. 38:p. 17]. While Mahan had created a complete analysis he still purported that strategy is all that pertains before, 'contact', of hostile armies and fleets [Ref. 36:p. 4].

2. Strategy: A Definition

While there were many examples cited in his works as to how naval strategy was employed successfully, there was not actually set down any guidelines as to how a strategy was derived using the principles set forth. It was later theoreticians building upon Mahan's work that more thorough explanations of strategy began to come to light.

One such rigorous explanation of naval strategy was put forward by H. E. Eccles when he stated that [Ref. 40:p. 12],

Strategy is the comprehensive direction of the power to control situations and areas to attain broad objectives.

This statement was further analyzed with the following conclusions [Ref. 40:p. 13]:

1. Strategy is comprehensive-it aims at the whole field of action.
2. Strategy is the direction of power. It should not concern itself with operational details.
3. Strategy deals with all forms of power available to the command.
4. Strategy deals with situations and areas, i.e. peoples attitudes and behavior, relative positions and lines of communication, chokepoints, material resources, combat bases, etc.
5. Strategy and destruction are not synonymous.
6. Strategy uses destruction only where there are no other means of control.
7. Strategy controls both the application of power and the resources of power.

A key word in Eccles' analysis is, 'control'. Control as related to strategy is described by H. Rosinski as [Ref. 41:p. 64],

. . . the element of control is the essence of strategy: control being the element that differentiates true strategic action from a haphazard of improvisations.

Therefore it is strategy, in contrast to haphazard action which aims to control the field of action whether it is military, political, or intellectual. Strategy must be comprehensive in order to control every possible variety of response.

Comprehensive control of the field of action lies in concentration upon the minimum number of key lines of action or key positions from which the field can be positively controlled [Ref. 41:p. 64]. With more rigorous definitions of strategy and control as background, application to the principles as laid down by Mahan are in order.

3. Fundamental Principles

Due to the difference between sea and land warfare Mahan had the formidable task of deriving the relations between Jomini's axioms and his analysis. On the subject of central position and interior lines he stated [Ref. 36:p. 51]:

The characteristic of interior lines is that of the central position prolonged in one or more directions, thus favoring sustained interposition between separate bodies of the enemy; with the consequent power to concentrate against either, while holding the other in check with a force possibly inferior.

Mahan saw that a strong central position, coupled with interior lines of communications, enabled one to assemble more rapidly than the enemy on two opposite fronts, which allowed a more effective use of forces, i.e. comprehensive control. Mahan stated that the strong central positions

were to be found at the geographical choke points, i. e., the Straits of Gibraltar, the Kiel Canal, the Panama Canal, and others. With the careful connection of one central position to another it gave access to many interior lines. The maritime interior lines eluded to were found on the route by Suez instead of the Cape of Good Hope, and the Panama Canal rather than Cape Horn. So there would be no mistake as to what Mahan had meant he gave a further, and simpler example [Ref. 36:pp. 51-52],

These instances of "Interior" will recall one of your boyhood's geometrical theorems, demonstrating that, from a point interior to a triangle, lines drawn to two angles are shorter than the corresponding sides of the triangle itself. Briefly, interior lines are lines shorter in time than those that the enemy can use.

Once the central position and interior lines were in place, there had to be distinctions between their offensive and defensive characteristics. When describing the inherent differences in communications Mahan stated [Ref. 36:p. 52],

"Communications" is a general term, designating the lines of movement by which a military body, army or fleet, is kept in living connection with the national power. This being the leading characteristic of communications, they may be considered essentially lines of defensive action; while interior lines are rather offensive in character, enabling the belligerent favored by them to attack in force one part of the hostile line sooner than the enemy can reinforce it, because the assailant is nearer than the friend.

While there had been much enumeration on interior lines Mahan made further statements on the defensive character of lines of communication. Mahan held that lines of communication, compared to almost anything else should be

safe, and therefore represent the most likely line of retreat a force may take should a reverse be experienced. In the direct application of this principle to naval strategy, i.e., that one must always guard one's line of communications, Mahan determined that secure communications at sea depend on naval preponderance, especially if the distances between the home and advance bases are great [Ref. 38].

With the establishment of central position, interior lines and communications they enabled the controlling force to 'concentrate', these advantages upon the enemy. While Mahan gave many good examples of concentration, it was Sir Julian Corbett who summed up the principle [Ref. 42:p. 118],

The object of Naval concentration ... will be to cover the widest possible area and to preserve at the same time elastic cohesion, so as to secure rapid condensations of any two or more parts of the organism, and in any part of the area covered, at the will of the controlling mind; and above all, sure and rapid condensation of the whole at the strategical center.

It is a visualization of the spider on a web that brings all the points Mahan has made under one roof. The central position is the center of the web and the rays emanating from the center are the interior lines which lead to the edge. The edge of the web represents the maximum area that can be patrolled and utilized. If the spider suffers a reverse at the edge, the interior lines then become defensive in nature and are the first lines of retreat. It is for this reason that they must be guarded.

4. Strategic Positions and Lines

The strategical center, as mentioned by Corbett, was different in naval strategy than in land warfare. Mahan had learned from Jomini that every area of operations had its strategic points. Mahan identified these strategic points as: (1) the base, the possession of which provides first the ability to launch an offensive operation, or gives logistic support, or in the case of reverse, protection; (2) the second strategic point is that place which the fleet occupies. This implies that the fleet must have a superior force [Ref. 36:p. 46]. Mahan on the subject of bases and the fleet at sea stated [Ref. 38:pp. 200, 8]

Notwithstanding the difficulty of maintaining distant and separate dependencies, a nation which wishes to assure a share of control on any theater of maritime importance cannot afford to be without footing on some of the strategic points to be found there. Such points suitably chosen from their relative positions, form a base; secondary as regards the home country, primary as regards the immediate theater. . . . The principle . . . is that of keeping a superior force at a decisive point; expressed in the homely phrase of getting there the first with the most men.

In regards to what constituted a strategic position Mahan proposed three conditions; situation, intrinsic strength, and resources [Ref. 36:p. 68]. When explaining what was meant by , 'situation', he stated [Ref. 36:p. 69],

Generally the value of the situations depends on the nearness to a sea route; to those lines of trade which when drawn upon the ocean common, are as imaginary as the parallels of the chart, yet as really and usefully exist. If the position be on the two routes at the same time, that is, near the crossing the value is enhanced. A cross-road is essentially a central position,

facilitating action in as many directions as there are roads.

Before the age of steam, these had been the intersection of the routes favored by the tradewinds. With the pre-eminence of steam these became the intersections of the great circle routes upon the chart.

When speaking of intrinsic strength he stated that it was both offensive and defensive in character. Furthermore, he stated that defensive strength depended upon permanent works [Ref. 36:pp. 70, 74]. Upon further analysis of defense he quotes Corbett * who in turn takes a maxim of Clausewitz and states, [Ref. 36:p. 89],

When we say that defense is the strong form of war, that is, it requires a smaller force if soundly designed, we are speaking, of course only on one certain line of operations. If we do not know the general line of operation on which the enemy intends to attack, and so cannot mass our force upon it, then defense is weak, because we are compelled to distribute our forces so as to be strong enough to stop the enemy on any line of operations he may adopt.

It is this strength upon a single line of approach which puts the attacker into a situation of continual movement, which makes him liable to mistakes. This is the true advantage of defense [Ref. 36:p. 87].

Mahan knew that offense and defense were different faces of the same coin. Only through a strong defense could one effectively conduct a successful offense. To creat the

* Corbett used the term 'line of operation' rather than communication.

strength needed for this defense there had to be natural resources. Natural resources, would provide more intrinsic strength than a position where they had to be brought in. As a final statement concerning strategic positions Mahan postulated that [Ref. 36:p. 50],

Where all three conditions, situation, intrinsic strength, and abundant resources, are found in the same place, it becomes of great consequence strategically, and may be of the very first importance

From these strategic points, issued forth the strategic lines, and those that were the most important were communications. The communications of which Mahan spoke were logistics, and those with the government. Mahan believed these to be the most important single element in strategy, either military or political. It is the control of these which lead to pre-eminence in sea-power [Ref. 36: 76-78].

5. Blockade

While all this looked great on the surface Sir Julian Corbett took issue with Mahan over many of the definitions that were proposed. Corbett felt that there were major differences between land and naval strategy that had not been addressed. The first issue brought forth was that of concentration of force. Corbett stated the fundamental difference as [Ref. 42:pp. 140-142]

In naval warfare we have a far-reaching fact which is entirely unknown on land. It is simply this - that it is possible for the enemy to remove his fleet from the board altogether. He may withdraw it into a defended

port, where it is absolutely out of your reach without the assistance of the army. No amount of naval force, and no amount of offensive spirit, can avail you.

When addressing the question of whether strategy is mainly definite lines of communications he stated [Ref. 42],

In land warfare we can determine with some precision the limits and direction of our enemies movements. We know that they must be determined mainly by roads and obstacles. There is nothing like this on the face of the sea to assist us in locating him and determining his movements. . . . Consequently in seeking to strike our enemy the liability to miss him is much greater at sea than on land, and the chances of being eluded by the enemy whom we are seeking . . . handle to maxim of "Seeking out the enemy's fleet", with caution.

The last issue was that of concentration of effort. Mahan had stated that you should keep a single eye on the force you wished to overthrow without regard to ulterior objects [Ref. 36:p. 61]. Corbett believed that you concentrated on trade at the expense of the enemies fleet or vice versa. If you tried to concentrate on both you would compromise both. Corbett stated at this point that, ". . . the enemies coast should be our frontier." [Ref. 42:p. 144] This could have but one explanation and that was blockade.

Blockade was the ultimate form of sea denial. Its use answered many of the questions that Corbett had put of Mahan. There were distinctive outlines of the coast and it also produced a vehicle whereas one did not have to compromise merchant shipping to sporadic enemy attacks. Mahan had covered the topic of blockade but had approached it from a different vantage but, the results were the same.

Mahan believed that blockade could be divided up into three different types: (1) commerce destroying; (2) commercial blockade; (3) and military blockade.

In utilization of commerce destruction one could in theory destroy the enemy through the destruction of his livelihood. As Mahan stated [Ref. 36:p. 92],

To attack the commerce of the enemy is therefore to cripple him, in the measure of success achieved, in the particular factor which is vital to the maintenance of war. Moreover, in the complicated conditions of mercantile activity no one branch can be seriously injured without involving the others.

While this was called financial and political 'commerce destroying', in the military sense it was strictly analogous to impairing the enemy's communications. This was an option open to small navies who were near their adversaries; and usually conducted against unarmed and unprotected merchantmen. The French called this action, 'Guerre de course' [Ref. 36].

Commercial blockade on the other hand, was the complete closure of ports to ingress and egress. It was not considered a military operation in a sense because it did not involve fighting, nor capture. In addition, it was not directed against military ports unless they were also centers of commerce. Its effects never the less were devastating to any economy which it was brought against [Ref. 36].

The military blockade is just what it purported to be. It is a blockade of specific ports where the enemy fleet is stationed. This endeavor is accomplished by stationing a competent force before the enemy's harbor therefore interdicting the lines of communications to his fleet. Due to the confining nature of the military blockade, the enemy is unable to defend the shipping so vitally needed to maintain ongoing efforts needed in warfighting. This is seen as a way that one could conduct with least effort the interdiction of the enemies communications. This again, is reminiscent of Corbett's, and Rosinski's comprehensive control and economy of effort.

6. Summary

Mahan, in his analysis of naval strategy, stated that there were three things which led to successful naval strategy. These were: (1) central position; (2) communications; (3) and concentration. It was his successors which laid the bases for more rigorous definitions of strategy by using Mahan's earlier dictums. By utilizing more stringent definitions, Mahan's successors demonstrated that strategy was comprehensive and must possess a world view. It is this comprehensive view that allows the strategist to concentrate naval force on a number of key positions or lines, with economy of force.

In order to concentrate one's fleet there had to exist a central position and interior lines of communications. The interior lines were time sensitive and allowed the attainment of position sooner than the adversary. This could only be achieved if one had naval preponderance or a strong defensive base. The base existed so that the fleet if suffering a reverse could retire from its field of action along defensible lines of communications.

While this theory of naval strategy held if the enemy was at sea, it did not hold if the enemy refused to take the field and stayed in port. With this situation, the concept of naval blockade was explored and subsequently divided into three specific areas: (1) Guerre de Course (commerce destroying); (2) commerce blockade; (3) and military blockade. The interrelating factor of all the blockade systems was that of commerce disruption by interdiction of the sea lines of communication. It was felt that this interdiction, would bring an early end to the conflict on favorable terms.

D. DISCUSSION: MAHAN AND THE LIMITING LINES

There is not a reason at this point in time for there to be conflict in space. But, Mahan has stated that as resources and room to conduct operations become more

restricted, then there will be conflict * over who is entitled to the larger share. To avert this possibility of being divested of sovereignty ** Mahan stated [Ref. 38:p. 200],

. . . a nation which wishes to assure a share of control on any theater of maritime importance cannot afford to be without footing on some of the strategic points to be found there...

The questions remain as to where these positions are, and can the US occupy them in order to ensure that its policy goals are met? The following will be a blending of Mahan and orbital mechanics in order to elucidate, by analogy, these areas of central position.

1. The Panama Theory

In 1960, a seminal thinker in the affairs of space, Dandridge M. Cole, put forth the Panama theory. The theory stated [Ref. 43:p. 6],

There are strategic areas in space--vital to future scientific, military, and commercial space programs--which must be occupied by the United States, lest their use be forever denied us through occupation by unfriendly powers.

When writing a further explanation in his book, "Exploring the Secrets of Space", Cole stated [Ref. 44:pp. 265-266]:

* Conflict as referred to here is economic, political, diplomatic, and military.

** There is by treaty no sovereignty in space, it is at this time free for all parties. Sovereignty in this sense is meant current orbital positions (GEO), Low Earth and Geo-synchronous inclinations, or altitudes.

. . . This is called the Panama theory in analogy with the strategically significant Panama Canal, since it is believed that some areas in space will come to have the same kind of importance in future planetary operations.

Some possible areas are the poles of the moon (because of the possibility of finding water there), the earth-moon libration points (such as the zero gravity point between the earth and the moon) and perhaps some of the asteroids.

What Cole was eluding to was Mahan's dictum of central position. In order to characterize the central position in space, it is easier to speak of the platforms and orbits already in use and then extend the argument into future orbital considerations.

a. Satellites

Satellites by their very nature as 'pickets', are afforded very little in the way of central position, or defensible lines of communications. Due to current treaties, satellites fall under the orbital heading of, possession is nine tenths of the law. By the nature of their function i.e., surveillance, weather, navigation, SAR (Search and Rescue), early warning, communications, and earth resources there are certain orbital slots which enable to satellites to conduct their function better than others. As more and more countries realize the benefits of space, the problem of orbital crowding will begin to take place. In addition, the earth's land masses are concentrated and separated by large bodies of water. This means, as Cole pointed out, that there are orbital positions of greater value than others.

This problem is further complicated by satellites having little if any maneuvering capability. These weak defensive lines make their destruction by space mine rendezvous, or that of an earth launched weapon a paramount problem of security.

b. SDI

The Strategic Defense Initiative is, by analogy, a military blockade. If the Soviet's, or some other belligerents Long Range Ballistic Missiles (LRBM) in their silos, can be considered to be ships in port then the definition fits. While SDI will be much like the satellites with limited maneuvering capability, they do, by their location hold a central position.

Missiles, based upon their payload and launch sight, must fly a path of least energy to their intended target. The missiles expend most of their energy in the boost phase climbing out of the gravity well. This launch trajectory is predictable and takes time. Therefore, as Mahan had stated, defense is the stronger form of war if there is but one line of advance and there exists the ability to exploit it. The LRBM, based upon the criteria above, have but one line of advance. By knowing the launch site and the missile launch capability you can compute the path of advance and counteract it.

c. The Space Station

The space station being a manned platform has some distinctly different problems. Until there is the realization of what von Puttkamer labeled as phase three (closed life cycle support), then there is a weak defensive line of communication. Upon the completion of phase three then the space station has all three strategic qualities; situation, intrinsic strength, and natural resources.

The space station also possesses numerous interior lines of communications. Earth's gravity plays powerfully into the space station equation. Due to the gravitational inverse square law, a space station launch is able to obtain a higher orbit faster than a vehicle launched from below the station's location. In instituting a launch toward the earth, gravitational acceleration becomes infinite unless acted on by some outside force. The space station has the added ability to be strong defensively. Given that an object is on an intercept course it is following the path of least energy *. By using the previously presented arguments and knowing the path or route, allows the employment of the Mahanian dictum of concentration. By concentrating force on the line of advance it presents the opportunity to disrupt that line of

* This is dealing with only space or earth launched vehicles/weapons and not with particle beam or laser weapons.

communication. Disruption, should be able to be accomplished by using an economy of force due to the advantage of comprehensive control over that line of communication.

d. High Earth Orbit

All of the above principles can be extended to high earth orbit. It is the phenomenon of gravity, time, and physical parameters which make being in high earth orbit even a more viable option for control. It must be remembered that it takes hours for an object to reach HEO altitudes. It is this time which give the occupant of the central position time to react to the environmental stress being added to the system. G. Harry Stine wrote in, "Confrontation in Space", that the higher up the gravity well the better. His analogy was two men, one at the bottom of a well and one at the top. If they both throw rocks at one another, "who gets hurt [Ref. 31]?" While the analogy is simple, it illustrates the principle aptly. The reason the man at the top never gets hit is that he can see the path of the stone and move out of the way. The principle of central position on the gravity well and interior lines of communications are even more pronounced in HEO if there has been a conscious effort to construct lines of communications between previously held central positions.

e. L1: The Ultimate High Ground

While it was mentioned that L1 was unstable, it lies approximately where the earth-moon gravitational field cancel. It has the added value as Mahan had stated as being at the cross-roads of trade. The central position held at L1, would allow one to control the whole earth-moon system, stable libration points (L4, and L5), and the access to trans-lunar space. If as Mahan has stated, you have been judicious and placed together many strong central positions, i.e. LEO, HEO, and L1 then you have maintained the integrity of the interior lines of communications, plus there are defensive lines to fall back upon if there should be a reverse. If as von Puttkamer has stated that the moon can be utilized as a resource basin for the maintenance of space based activities, then the instability of L1 is a problem that can be managed.

2. Summary

The idea that to remain successful in a theater one had to have a footing on strategic ground was first put forward by Mahan in response to the rapid expansion of the world into new spheres of influence. The similarity between that and expanding into space was recognized and explained by D.M. Cole in the early 1960's. Cole recognized the strategic importance of many areas in space and put forth the 'Panama Theory' but, the point remains it was Mahan and his naval strategy which provided a backdrop for many of these

later theorist's. The point being, that Mahan has given a recipe for space expansion which will fill the goals of the US Space Policy, and at the same time ensure that we are not excluded from exercising our rights in space.

The rules of physics apply in that, to place an object in space it must follow the path of least energy. This path of least energy is analogous to Mahan's, great circle routes on earth, which therefore give an earth or space launched vehicle predictability. This predictability is what makes a defensive central position strong since there is but one path of advance.

These paths of least energy allow one to apply the principle of comprehensive control, and allows the concentration of effort with the greatest economy. It is for this reason that Mahan had a great deal to say about the expansion into space.

V. CONCLUSION: MANAGEMENT OF SPACE STRATEGY

A. INTRODUCTION

As the United States enters the 21st Century, the keen competition for limited resources will accelerate. One of the resources available to help solve many of the US's current problems, is space. This thesis began by comparing the US Space Policy document with that of our main competitor, the Soviet Union. While the need for national security is paramount, that is where the similarity in the two documents ends. As the United States wrestles with the problems of staying economically competitive with foreign space programs, the Soviet Union is working at the systematic and incremental exclusion of the US and other international powers from space. This is a problem of utmost strategic importance, and what this thesis addressed itself to.

The strategic management of space was examined with the support of a systems model. The model was developed to aid in the organization of the large bodies of knowledge which are currently available on the subject of space. Upon integration of the various pieces of the model, a coherent framework was established giving a visual picture of the interrelationships. By visualizing the complexity of the interactions, it allows one to arrive at an appropriate

strategy knowing, that all the interactions have been accounted for, or taken into consideration.

The model used was first proposed by C. West Churchman. Churchman's model divided the system into five major parts: (1) the environment; (2) resources; (3) components; (4) planning; (5) and control. The elegance behind the construct was that each undifferentiated body of knowledge could be tested in order to ascertain its proper place within the structure of the model. Once the structure was established, the thesis analysed each constituent part in order to define its effect on US Space Policy.

B. ENVIRONMENT: PRESENT AND FUTURE SPACE TRENDS

The first area of the model analysed was the environment. The environment consisted of foreign space programs and the projected future of space. The foreign space programs selected were those that could launch, track, and maintain their own space vehicles. The analysis determined that the programs had several intrinsic goals: (1) solving of current national problems; (2) offsetting the cost of the individual space programs by becoming competitive in the international booster market; (3) and eventual industrialization and creation of a manned platform in space. All three of these foreign goals directly or indirectly impinge on current US efforts in space.

The projected future of space was analysed to discern whether or not long range trends could be anticipated. The analysis revealed that the cost of current space efforts would soon become prohibitive, and that multinational efforts would be needed in the near future to make these ventures profitable. It was also noted that the promise of new markets, and a healthy return for the initial investments would continue to be the driver of these continued space efforts.

The extended future examined man's eventual resettlement of the moon and continued interplanetary missions. The prospect of almost unlimited resources for space based manufacture, residing in the asteroid belt, would ensure that the competition in space would continue for a long time.

In order to cope with the complexities of international competition, and the military superiority aspect of the Soviet Union's drive into space, a look was taken at the intrinsic portions of the model. The resources and the components that reside within the systems boundary are what can be utilized to help resolve these problems of strategic complexity. While this thesis covered the topic of resources lightly, it was considered to be the strongest/weakest portion of the system.

C. COMPONENTS: PHYSICS AND MAHAN

The components of the model dealt with orbitology/orbital mechanics, and the maxims of Mahan, et al. The orbital mechanics section of the component piece was analysed to demonstrate that spacecraft, in order to remain economical, flew a least energy trajectory. This Hohmann transfer was shown to be the same whether the spacecraft was being launched, making an orbital transfer, or a rendezvous. It is this least energy trajectory, which is analogous to the great circle routes upon the planets surface. Once the mechanics portion of the analyses had been completed an examination of orbital topography was conducted. This was undertaken to show which areas around the terrestrial sphere were utilized most heavily, and to give some dimension to areas that would be addressed later in the thesis.

The second, and equally important component piece, were the maxims of Mahan. Mahan, had distilled Jomini's axioms of war into three major themes: (1) central position; (2) communications; (3) and concentration of force. Central position was explained to be both, where the fleet resided at any particular time, or a strong naval base or port that could be defended.

A strong central position as described by Mahan had to possess: (1) intrinsic strength; (2) situation (nearness to sea routes and lines of trade); (3) and abundant resources.

By possessing these three essential qualities, it allowed one to have secure lines of communications.

These communications were at the same time, both offensive and defensive. The offensive, or interior lines allowed one to reach the crucial area of contention faster than one's adversaries. But, should a reverse occur then these interior lines became defensive in nature and allowed withdrawal in relative safety. These lines of communication were to be guarded at all times due to the reasons stated above, plus the fact, that strong central positions could be linked together if there was adequate protection provided. In addition, these lines of communications provided the means, for a naval arm, to apply a concentration of force upon the weak area of another belligerents defenses.

While all of what Mahan had stated looked fine on the surface, it was Sir Julian Corbett, who stated that unlike land warfare, the enemy could remove his players from the board altogether. It was this reality that sparked the strategic question of blockade. Blockade was for simplicity, divided into three categories which are as follows: (1) commerce destruction; (2) commerce blockade; (3) and military blockade. While the first two types of blockade were conceived to effect the enemy's war making capacity, the third was designed to nullify the means of war making altogether. It was this nullification, which was seen by many, to be the true function of the naval force.

D. MAHAN AND SPACE

Upon combining Mahan and orbital mechanics, the analogous situation between space power and sea power becomes apparent. It was the purpose of this thesis to show that through careful orbital selection one could achieve either: (1) a military blockade; (2) strong defensive central position; (3) and/or secure lines of communication. With a strong defensive central position, one could utilize the physics of orbital mechanics to secure ones lines of communications. This is accomplished by using the inverse square law of gravity, combined with the least mechanical energy needed for the operation. By conducting operations this way it allows several things to happen: (1) depending upon your placement within the gravity well, you either achieve infinite acceleration when moving toward a massive body, or the ability to use less energy to achieve a higher altitude; (2) by reversing this process you can compute the trajectory your competitor must fly in order to reach you; (3) and by continuing to follow this logic, it allows one to husband energy making materials which allows the presence in space to be longer than the competitor.

In addition to the above arguments was posed the question of strategic central positions in space, and their locations. Cole's 'Panama Theory', described the choke points in space to be directly related to position on the gravity well (altitude), the earth-moon libration points,

the moon, and the asteroid belts. The areas as described, commanded the space lanes of communication, allowing one to observe movement within the orbital medium. It is the securing of these points for one's own use which provides the ability to remain competitive, fulfill policy goals, and to ensure ones continued presence.

In conclusion, the systems theory model provides the positive feedback needed to implement the naval strategy of Mahan (as applied to space), and to control the outside stresses of numerous space programs, and an unseen future. It is this idea of control, with an economy of force which was the genius of Mahan.

APPENDIX A

Orbital Selection Criteria

The following will describe some of the engineering criteria that are considered when putting a vehicle into orbit.

Space System Design

1. Orbit Selection.
2. Number of satellites (constellation size).
3. Definition of spacecraft payload (what will it be used for: mission statement).
4. Decision whether to configure for manned or unmanned vehicles.
5. Size, weight, and configuration of spacecraft.
6. Launch vehicle needs (gantries, pad size, type of fuels, etc.).
7. Ground support (tracking sights, telemetry, tracking, and control, recovery systems).
8. Cost estimates.

Space Environment

1. Atmospheric drag (becomes less as altitude increases).
2. Expected lifetime of the spacecraft (the lower the altitude, the shorter the life of the vehicle).

3. Natural radiation (solar and earth albedo) and the radiation experienced from the Van Allen Belts.
4. Micro-meteoroid damage.

Sensor Coverage

1. When can the satellite first see the target or ground station?
2. What is the length of time the satellite stays in contact?
3. What is the slant range to the satellite (elevation angle)?
4. The higher the altitude the greater the contact time and the angle above the earth.
5. The foot-print (beam width) upon the earth. The beam diameter is larger the higher the orbit.
6. The swathwidth cut by the sensor follows the same pattern as beamwidth.
7. Revisit time in the orbit, how many times the satellite returns to the same area within a 24 hour period.
8. Sun-synchronous orbits using the shadowing effects of the sun for greater resolution of surface irregularities.

Resolution

1. The ability to distinguish two objects as separate objects.
2. Factors that affect resolution are atmospheric turbulence, smearing due to spacecraft motion, quality of the optics, resolution cells, or antennas, and the size of the optics, resolution cells, or antennas.

Survivability

1. The higher the altitude the greater the survivability.
2. Advantages and/or disadvantages of higher altitudes include (perspective dependent): (1) detection limits and performance of ground base sensors; (2) Cost of interceptors (ASAT), increases with altitude; (3) guidance and accuracies of ground controlled (ASATS).
3. Spacecraft must be structurally heavier.
4. Greater engineering problems due to EMP (Electromagnetic Pulse) hardening.
5. Greater systems redundancy, which translates into larger weight requirements.
6. Cost is directly related to survivability in general systems design and selected launch vehicles.

Transmitter Power and Data Rate

1. With space based assets there is a need for:
 - a. High data rates.
 - b. High signal to noise ratios.
 - c. Large bandwidths.
 - d. Low error rate in data transmission
10exp-5 bps is standard.
 - e. High power.
 - f. High grade electronics with the latest techniques for bandwidth exploitation.

Payload Limitations

1. With current booster technology the overriding factor is weight.
2. The more complex the satellite the greater the weight.

APPENDIX B

Maritime Force: The Analogy to Space

The purpose of this paper is to indicate some ways that conflict in space is analogous to conflict on the seas. The following are salient characteristics of sea warfare [Ref. 34].

Strategy

1. Sea Power aims to influence circumstances on land --where people live--and is in that sense subordinate to land power.
2. Command of the sea leads to the exercise of sea control, which aims to influence circumstances on land.
3. Relatively few major battles occur at sea, due to their decisiveness in potential or fact.
4. The overlap of interaction between land forces to seaward and vice versa is growing because of the increase in sensor and weapon range.
5. Bases are vital elements for their logistic value and for the destruction of forces caught in or near port.

Vehicles and Their Bases

1. Are large and expensive; few in number and highly valued.
2. Are characterized by longer range sensors and communications than ground combat elements so targeting and concentrated attack is easier.
3. Are self contained for long periods.

4. Are large, fixed, vital and must be safeguarded as potential Achilles heels.

Combat Processes

1. Naval combat is attrition-centered.
2. Firepower, scouting (Razvedka), and C2, along with their antitheses which attempt to interfere with the enemy's three processes, are the six essential processes of naval combat.
3. Maneuver of vehicles has become less important vis-a-vis maneuver of weapons.

Time and Timing

1. Longer ranges of weapons and sensors create the need for great foresight and anticipation.
2. Explosive action and decisiveness characterize sea battle, with a time lag between the visible attrition and the key decisions which brought it about.
3. The duration of the battle action tends to be faster paced than on the ground. But if the preliminaries are included, the duration of the battle may actually be slower, depending on how its beginning is defined.

Physiological

1. Sea sickness is suffered by seamen.
2. Life is at close quarters.
3. Life of seamen breeds attitudes characteristic of closed societies.

Science and Engineering

1. Navies have a long tradition of emphasis on technical competency. Army leaders think about strategy and tactics; naval leaders think about better weapon systems that are smoothly operated.

Summary of Inferences Regarding Space Warfare

1. Doctrine and matters of leadership will be underappreciated in space warfare circles, unless emphasized from the outset.
2. Combat will be infrequent, but the capacity to fight and win will be vitally important.
3. The influence of space systems will be underappreciated by the uninitiated and the ability to dominate in space (win a space war) undervalued until the battle is lost.
4. In the building of a space warfare capability watch for:
 - a. The importance of scouting (very long range detection, tracking, and targeting).
 - b. Great anticipation, encompassing great distances.
 - c. Technological ways to get to close quarters such as "stealthy" spacecraft.
 - d. Attacks on bases on the ground.

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